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(19) (CA) **CANADIAN PATENT** (12)

(54) EXPANDING HOLLOW TUBE ROCK STABILIZER

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APPLICATION OF: JAMES C. SWAIN, JAN B. YATES & DAVID L. THOMAS  
FOR: EXPANDING HOLLOW TUBE ROCK STABILIZER

ABSTRACT OF THE DISCLOSURE

A hollow, elongated tube is inserted without substantial interference into a bore hole in a rock formation having a diameter at least substantially as large as the largest cross sectional dimension of the tube. After insertion, a mandrel or other expansion means is forced through the tube to expand the latter into frictional engagement with the bore hole wall, thereby reinforcing the rock strata surrounding the tube. In a first embodiment the tube is folded along one or more axial lines to a non-circular configuration, the mandrel serving to at least partially unfold the tube. In a second form, the tube is of circular cross section and remains so as it is stretched by the mandrel into contact with the bore hole wall.

## BACKGROUND OF THE INVENTION

The present invention relates to stabilization of rock structures for mining operations, and the like, and more particularly to rock stabilizers of the type wherein an elongated, hollow tube frictionally engages a bore hole in the rock formation.

10 In underground mining and other tunneling operations it is necessary to support the roof, and sometimes the walls, to prevent rock falls or cave-ins. This is normally accomplished in current practice by drilling holes into the rock structure surrounding the tunnel at certain intervals and anchoring an elongated member such as a bolt, rod or tube in the hole to hold a plate in supporting engagement with the rock face surrounding the drill hole. The more common anchoring means include mechanical expansion anchors, hardenable resin grouting mixes, and frictional engagement of tubular structures with the drill hole surface.

20 Among the latter types of anchors or stabilizers are those disclosed in U.S. Patents Nos. 3,349,567 of Munn, 3,922,867 and 4,012,913 of Scott, and 4,126,004 of Lindeboom. The stabilizer disclosed by Munn comprises a hollow steel tube of annular cross section having a bore hole into which it is inserted; the tube is expanded into contact with the bore hole wall at a number of discrete points by magnetic fields induced by high voltage electrical discharges from a wand inserted into the tube. The stabilizers of the Scott and Lindeboom patents are all hollow tubes of annular cross section larger than the bore hole; the tubes are forcibly driven into the hole, thereby undergoing circumferential compression and plastic

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deformation, to frictionally engage the bore hole wall along the entire inserted length.

10       Hollow tube stabilizers such as that of the Munn patent are in frictional contact with the bore hole wall at only a few discrete points, rather than continuously along their entire length and are thus of limited holding force. The Scott & Lindeboom stabilizers, while providing continuous contact and holding force along their entire length, must be forcibly driven into the hole. Therefore, caution must be exercised to avoid bending, buckling or other structural damage to the tube as it is contacted with a suitable driving tool, especially in the early stages of insertion. Furthermore, although pneumatic impact tools of sufficient driving force to effect insertion of the tubes are generally available in hard rock, metal mines, such is not often the case in coal mines which normally employ hydraulic equipment for installation of expansion anchor or resin grouted systems. As insertion progresses, the force required to drive the tube further into the hole will increase due to the larger area of frictional contact between the tube and hole walls.

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It is a principal object of the present invention to provide a tubular rock stabilizer which is placed in frictional engagement with the interior of a bore hole without encountering high frictional forces upon tube insertion.

Another object is to provide a tubular stabilizer which is initially of smaller cross section than a bore hole in the rock structure, thereby allowing uninterrupted insertion, and which is thereafter expanded to engage the bore hole wall along the entire inserted length of the tube.

A further object is to provide a hollow tube stabilizer

which may be placed in frictional contact with the wall of a bore hole in a rock structure, after being subjected to elastic and plastic deformation, with less driving force than similar tubular anchors presently in use.

Additional objects are: to provide a hollow metal tube stabilizer for frictional engagement with a bore hole in a rock formation which exerts a greater holding force per pound of metal (and therefore per unit cost) than prior art designs; to provide a hollow tube rock stabilizer which will function better than prior art designs in bore holes which vary in diameter from end to end, particularly those which taper to a larger diameter at the upper end; to provide a hollow tube stabilizer which may be increased in its frictional engagement with a bore hole in a rock structure at any time subsequent to initial installation; to provide a hollow tube, frictional contact, rock formation stabilizer which is more adaptable to use in longer sections than prior art designs; to provide a hollow tube stabilizer which is initially under tension when installed; and, to provide a hollow metal tube rock stabilizer wherein the entire axial strength of the tube is utilized.

In a more general sense, the object is to provide novel and improved rock stabilizers of the hollow tube type which frictionally engage the wall of a bore hole in a rock structure.

Other objects will in part be obvious and will in part appear hereinafter.

#### SUMMARY OF THE INVENTION

Broadly speaking, therefore, the present invention may be considered as providing a method of stabilizing and supporting

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a rock formation comprising the steps of: (a) boring a hole into a surface of the rock formation to a predetermined nominal diameter; (b) fabricating a hollow, elongated, tubular stabilizer having an insertion portion extending for at least a substantial portion of its length, the insertion portion having a maximum external transverse dimension not greater than the nominal diameter and comprising a wall extending for substantially the full length thereof and adapted for radially outward elastic and plastic deformation; (c) placing the  
10 insertion portion in the hole; and (d) moving a mandrel through the insertion portion to effect the deformation of the wall radially outwardly throughout the axial extent of the wall through which the mandrel is moved, thereby placing the wall in frictional, non-piercing engagement with the interior of the wall to provide an anchoring force on the rock formation.

The above method may be carried out by utilizing stabilizer means for installation in a bore hole of predetermined nominal diameter in unconsolidated underground rock strata to prevent separation and falling of portions thereof, the  
20 means comprising: (a) an elongated, hollow, body member having an insertion portion extending for at least a substantial portion of its length, the insertion portion having a maximum transverse dimension not significantly greater than the predetermined diameter, whereby the insertion portion may be inserted into the bore hole with little or no axial force; (b) the insertion portion comprising a non-perforated wall extending for substantially the full length thereof and adapted for radially outward elastic and plastic deformation; and

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(c) mandrel means movable through the insertion portion of the body member to effect the deformation of the wall thereof radially outwardly about substantially its entire perimeter throughout the axial extent of the wall through which the mandrel means is moved, whereby the strata is stabilized solely by frictional, non-piercing engagement by the exterior surface of the wall with the interior of the bore hole.

BRIEF DESCRIPTION OF THE DRAWINGS

10      Figure 1 is an elevational view of a first embodiment of the tubular stabilizer of the invention;

    Figures 2 and 3 are bottom and top plan views, respectively, of the stabilizer of Figure 1;

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Figure 4 is an elevational view of the stabilizer of Figure 1 in axial section on the line 4-4 thereof, shown inserted in a bore hole in a rock structure, also shown in section prior to expansion of the tube;

Figure 5 is a sectional view on the line 5-5 of Figure 4;

Figure 6 is an elevational view in section, as in Figure 4, after expansion of the tube;

Figure 7 is a sectional view on the line 7-7 of Figure 6;

10 Figure 8 is an elevational view of a second embodiment of the stabilizer, also shown in section within a bore hole with the mandrel partially inserted;

Figure 9 is a sectional view of the stabilizer of Figure 8, taken on the line 9-9 thereof;

Figure 10 is an elevational view showing an alternate type of expansion device; and :

Figures 11-13 are a series of cross sectional plan views of a modification of the stabilizer of Figures 1-7 shown prior to, during and after expansion within a bore hole.

#### DETAILED DESCRIPTION

20 Referring now the drawings, the reference numeral 10 denotes the hollow, tubular body portion of the stabilizer embodiment of Figures 1-5. Body 10 is constructed from hollow, metal tube stock which, in its conventional form, is fabricated in standard lengths by bending flat stock to circular cross section and welding the edges together. A suitable material for use in fabricating the stabilizer of the present invention is 1020 CRS electric welded tubing having an outside diameter of 1.50", wall thickness of .068" and ultimate tensile strength of



60,000 to 70,000 psi by pull test.

10 In forming body 10 the tubing outer wall is indented, as by a pressure roll, along axial lines at four equally spaced intervals about its periphery for the entire fabricated length of the tubing. The inwardly indented or folded areas are denoted generally by reference numeral 12. Although steel tubing may be fabricated in virtually any desired length, and body 10 of the stabilizer may be provided in various lengths, in the usual case it is more convenient to fabricate the tubing in lengths considerably longer than the desired length of body 10. For example, the tubing may be fabricated in 30 foot lengths and cut, preferably after the axial folds are made, to lengths of 5 or 6 feet.

20 After the tubing is folded and cut to the desired final length of body 10, one end thereof is expanded outwardly to the original circular cross section of the tubing and the other end is crimped or tapered to a smaller dimension, for reasons explained later. The open and crimped ends are respectively denoted by reference numerals 14 and 16. Ends 14 and 16 are hereafter termed the lower and upper ends, respectively, of body 10 since these are the positions they assume when inserted upwardly into a drill hole in the intended manner. Lower end 14 may be expanded by forced insertion of a mandrel of appropriate dimensions.

Steel ring 18, having an inside diameter, substantially equal to the outside diameter of end 14 in its original or expanded state, is placed around end 14 and securely fastened thereto, as by spot welding at a number of points. Ring 18 may be a continuous circle or formed from flat stock bent to

circular configuration without welding or otherwise joining the abutting ends. It may be placed around end 14 after the latter has been expanded to its original circular cross section but is preferably positioned around end 14 prior to expansion so that the outer surface of end 14 is expanded into tight engagement with the inner surface of the ring prior to welding the two together.

10 After the expanding mandrel is withdrawn a substantially smaller mandrel 20 is inserted into end 14 and forced a short distance into the folded portion of body 10. As seen in Figures 4-6, mandrel 20 is in the form of a plug of circular cross section which tapers from a first diameter at the end facing lower end 14 of the stabilizer to a second, smaller diameter at the other end. Mandrel 20 is retained within body 10 near lower end 14, as shown in Figure 4, until the stabilizer is ready for use by means of a slight radial crimp or indentation of the tube body below the mandrel, or other appropriate means for maintaining the mandrel in association with body 10. Returning lower end 14 of body 10 to its original circular cross section provides a greater area for welding ring 18 to the stabilizer body, making an efficient coupling of the ring to tube forces, as well as providing a gradually tapering area for insertion of the mandrel into the folded portion of the body.

20 Of course, the mandrel and body portions of the stabilizer may be kept separate until ready for use with the mandrel being placed manually in the lower end of the stabilizer body just prior to or after insertion thereof into the bore hole. This has the advantage of allowing the selection of a

mandrel having a size matched to the hole size from a plurality of different sized mandrels, since hole size may be expected to vary somewhat even in holes made by the same drill. However, the possibility of operator error in choosing a mandrel of the wrong size is also introduced, as well as the undesirable requirement of additional manual operations at the point of use. It has been found that mandrels of a single size will operate in a satisfactory manner in holes which vary as much as 7% in diameter, which is the largest variation  
10 encountered under normal circumstances in holes drilled to the same nominal diameter. Thus, it is preferred that the mandrel be frictionally engaged, or otherwise captured or permanently associated, with body 10 of the stabilizer at the time of fabrication rather than being assembled therewith at the point of end use. Small indentations such as those shown in Figure 4 at 21 are made in two opposite folded areas 12 for this purpose.

In operation, a bore hole such as that denoted in Figures 4 & 6 by reference numeral 22 is drilled into a rock  
20 formation such as a mine roof to a nominal diameter slightly larger than the largest cross sectional diameter of the folded portion of body 10, i.e., the portion other than expanded lower end 14. A steel plate 24 of any conventional design used as a load bearing support in applications such as that of the present invention is placed in association with the stabilizer by passing body 10 through an opening in the plate. The diameter of the opening is approximately equal to the outside diameter of lower end 14, whereby plate 24 is supported upon ring 18.

10           Body 10 is then inserted into hole 22 until plate 24 is engaged with the surface of the rock formation surrounding the entrance to the hole. The inward taper of upper end 16 assists in guiding body 10 into the hole. No axial forces of any consequence are exerted upon the stabilizer during insertion into a straight hole since, as previously stated, the hole diameter is slightly larger than, and in no event smaller than the largest cross sectional dimension of the portion of body 10 inserted therein. Some axial force may be required if the bore hole axis is curved. The elements at this point are as shown in Figures 4 & 5. Mandrel 20 is then contacted by a suitable driving implement (not shown) such as a pneumatic impact tool, or a hydraulic drill boom of the type commonly used in connection with the drilling and mechanical bolting operations in coal mines. An appropriate force is applied by the driving implement to move mandrel 20 through body 10, expanding folded portions 12 thereof to an extent sufficient to bring a substantial portion of the outer surface of body 10 into engagement with the wall of bore hole 22. Mandrel 20 is moved to a position near upper end 16, as seen in Figure 6. The mandrel may be pushed all the way through and out of the upper end of body 10 without adverse effects.

20           With respect to Figure 4, it will be noted that ring 18 is in direct, supporting contact with plate 24, which in turn contacts and supports the surface of the rock formation surrounding the drill hole. Since the surface of ring 18 which contacts plate 24 lies in a plane normal to the axis of body 10, the forces transmitted between the ring and plate will

not be uniform about the periphery of the ring if the axis of the bore hole is not perpendicular to the plane of the surrounding rock surface. In actual practice, in fact, this is often the case. The transmitted forces may be distributed more evenly by providing a spherical rather than a flat contact area between the plate and its supporting element. One example of such arrangement is shown in Figure 6 wherein washer 25 is inserted between ring 18 and plate 24. Washer 25 has an internal, stepped shoulder for engagement with ring 18 and a spherical outer surface for contact with plate 24. In such applications, a spherical indentation is provided about the opening in plate 24, as indicated in the drawing. The use of a separate element such as washer 25 may be avoided, if desired, by forming a similar spherical surface directly on the portion of ring 18 which contacts plate 24.

It is preferred by that the extent of expansion of body 10, even in the largest holes, is such that portions of at least some of folds 12 remain after full expansion. That is, the outer surface of body 10 is not returned to a fully circular configuration. Body 10 need not be expanded symmetrically and, in practice, does not expand so in most cases. Mandrel 20 tends to migrate toward the side of body 10 where the weld is formed when the tubing is fabricated. Figure 7 indicates a typical expansion pattern. However, this does not deter in any manner from the performance of the stabilizer, or the holding force exerted thereby on the surrounding rock formation.

A lubricant is preferably provided on the inner wall of body 10 in order to minimize the force required to drive the mandrel through the body. Ordinary greases and oils have been

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found to provide little, if any, effect in reducing the driving force required. However, significant results are obtained by the use of lubricants such as those employed in drawing steel tubing over mandrels during fabrication thereof. An example of such lubricant suitable for use in the present invention is that sold under the trademark Reactobond 909 by O.M.I. Parker Division of Oxy Metal Industries Corp., of Madison Heights, Michigan. A convenient means of applying the lubricant is to dip the entire body 10 therein, thus coating both the inside and outside surfaces. Although coating the outside has no effect on the force required to drive the mandrel, of course, it does provide a measure of protection, as from corrosion, and does not reduce the holding power of the installed stabilizer.

Turning now to Figures 8 and 9, a second form of stabilizer is shown. In this embodiment, body 26 is of round cross section, comprising a length of conventional, hollow, steel tubing. Mandrel 28, in this case being spherical in shape, is inserted in expanded lower end 28 of body 26 which again has affixed thereto a ring 30 and support plate 32. Of course, mandrels of any suitable shape which produces the desired expansion may be used with either of the disclosed stabilizer body embodiments. Body 26 has a diameter initially smaller, or not greater, than that of bore hole 34 in the rock formation to be stabilized. Thus, body 26 may be inserted in hole 34 without exerting any substantial axial forces until plate 32 is engaged against the surface of the rock formation surrounding hole 34. Mandrel 28 is then forced through body 26 to a position near the upper end thereof, stretching the tube wall outwardly into tight frictional engagement with the wall of hole 34.

Since the body of the stabilizer is to be inserted without substantial interference, its outer diameter should be equal to approximately the smallest hole encountered under normal drilling conditions. As previously stated, hole size may be expected to vary up to perhaps 7%. Steels of suitable strengths for use in such applications have sufficient ductility to accommodate such variations in hole size before ultimate failure of the metal and still exert the necessary axial holding forces on the surrounding rock structure. However, a much greater variation in the driving force required to move the mandrel through the body is encountered when using a circular cross section stabilizer body than when using the folded body of the previous embodiment. For this reason, i.e., more uniform mandrel driving force over the anticipated range of hole size variation, the folded body embodiment is preferred over the circular cross section body. In addition, there is a substantially lower possibility of inducing harmful cracks in the rock strata surrounding undersize holes with the folded embodiment.

The mandrel used to expand the stabilizer body may take any of a variety of forms, in addition to those of the tapered plug and spherical mandrels shown in the accompanying drawings, and any suitable form may be used with either of the two disclosed embodiments of the stabilizer body. It is preferred that a relatively inexpensive mandrel be utilized and remain in the tube body after expansion. That is, it is preferred that the mandrels be expendable and, as previously mentioned, that a single, standard size (diameter) of mandrel be used with each tube size, for use with a particular nominal diameter of bore hole. However, the scope of the invention is also intended to

encompass designs utilizing recoverable mandrels which are either driven through the body from the lower to the upper end and then withdrawn or pulled from an initial position at the upper end through the lower end. In the latter case, it is obviously necessary to provide some means for restraining the stabilizer body against axial movement out of the hole as the mandrel is drawn therethrough.

10 In Figure 10 is shown an alternate embodiment of reuseable mandrel in the form of tapered screw 36 having a diameter at its upper end smaller than the inside diameter of at least the lower end of the tube body, and a maximum diameter equal to the desired extent of expansion of the body. Screw 36 is rotated as it is inserted into and through the tube, thereby effecting the desired expansion, and may be counter-rotated to assist in its withdrawal at which time the minimum inside dimension of the stabilizer body is substantially equal to the maximum diameter of the screw. The expander screw could be attached to and rotated by conventional mine bolting machines currently in use. If necessary, means would be provided in  
20 association with the bolting machine for gripping the ring on the lower end of the body to restrain the latter against rotation, at least in the initial stage of advancement of the screw until a sufficient portion of the body has engaged to bore hole wall to prevent rotation. A captured, expendable mandrel could also be provided in the form of a screw or other rotating structure.

In some mine roof support applications, the bore hole is made in two steps, drilling to a first depth at a first diameter to provide a so-called starter hole and then drilling



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through the end of the starter hole to a deeper depth at a smaller diameter in order to reduce the possibility of cracking the rock strata near the supported surface in small or under-sized holes. In such cases, the stabilizer engages only the smaller diameter drill hole wall, which may begin several feet from the entrance to the starter hole. When the present invention is utilized in such applications, the mandrel may be inserted in the tube at the time of fabrication to a depth equal to that of the starter hole wherein the stabilizer is to be employed. This has the advantage of requiring less time and energy for mandrel insertion at the point of use.

Although in both illustrated embodiments, the body sections of the stabilizer are of closed form in cross section, the invention also contemplates the use of open forms. That is, the abutting edges of the hollow tube formed by bending the initially flat stock to the circular configuration need not be welded to form a closed cross-section tube. In such cases, the stabilizer body would include an open axial slot along its entire length, which would provide manufacturing economies over welded tubing. Although such designs would not be practical in stabilizer bodies of circular cross section since the slot would simply be widened as the body is expanded and would tend to spring back and reduce the holding force, such is not the case with folded embodiments such as first described herein. Such a design is shown in Figures 11-13, wherein the stabilizer body is denoted by reference numeral 38. Body 38 is formed as a rolled section from flat strip stock, providing two adjacent but unjoined edges 40 and 42. As in the first embodiment, four inward folds or indented areas 44 are formed axially along the length of body 38.

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In Figure 11, body 38 is shown in its free state, as inserted into the bore hole prior to expansion. Figure 12 illustrates the appearance of body 38 just ahead of the mandrel as it is driven therethrough. Edges 40 and 42 have opened somewhat and are spaced further than in the initial, undeformed state as body 38 is expanded to bring contact surfaces 46 into engagement with the wall of the bore hole. Body 38 is shown in Figure 13 as it would typically appear at complete expansion by the mandrel. As the metal is pushed outwardly into folded areas 44, edges 40 and 42 are brought together and continued expansion brings the body cross section to a final configuration approximating that of Figure 5. In such constructions, as the mandrel is advanced it will normally shift toward the side at which the edges are unjoined, as indicated in Figure 13. Also, edges 40 and 42 may tend to turn inwardly after being brought into contact. In order to prevent edges 40 and 42 from riding over one another, i.e., overlapping as the body is expanded they may be provided with bent-over flanged portions or other suitable means (not shown).

From the foregoing description it is apparent that the present invention provides an economical and convenient means for stabilizing rock formations, including the support of mine roofs, and the like. The hollow tube-type anchor is inserted in the drill hole without undergoing significant axial stress, and is radially expanded into permanently gripping contact with all or a portion of the length of the bore hole wall over all or most of its external periphery. Using a single, standard size stabilizer body and mandrel, the system will operate satisfactorily in hole sizes which vary up to at least 7% in diameter.

In practice, it has been found that suitable designs of this type for use in nominal 1.425" diameter holes may be constructed from the previously mentioned 1020 CRS electric welded tubing having an initial outside diameter of 1.50" with four axial folds producing a maximum cross sectional dimension of 1.360"

( $\pm .005$ "), and minimum outer dimension of .89". In such a stabilizer body, a force of about 2,000 lbs. is required to advance a mandrel 1.020" in diameter when the body is not radially restrained, i.e., not inserted in a hole, about 3,000 lbs. when the stabilizer body is within the largest hole (1.475") and about 4,000 lbs. when in the smallest hole (1.375").

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Designs such as the embodiments of Figures 1-7 made of steel having 65,000 psi breaking strength have been found to exhibit a holding or stabilizing force on the rock formation equivalent to or greater than that of current oversize, forcibly inserted tubular anchors such as those of previously mentioned Patents Nos. 3,922,867 and 4,012,913 while requiring approximately one pound less steel per 5 foot length. Even greater savings in material, and therefore in cost, may be realized by employing higher strength materials. While the driving force required for insertion of the oversize tubular anchors increases steadily as the anchor is inserted, the force required to advance the mandrel through the initially undersize stabilizer of the present invention is substantially constant over the entire range of travel. Other advantages include the capability of increasing or restoring the holding force of the stabilizer by driving larger mandrels through the tube body subsequent to initial installation, and the use of longer stabilizers which are increasingly subject to buckling or other failure when high axial forces are exerted thereon.

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THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. Stabilizer means for installation in a bore hole of predetermined nominal diameter in unconsolidated underground rock strata to prevent separation and falling of portions thereof, said means comprising:

(a) an elongated, hollow, body member having an insertion portion extending for at least a substantial portion of its length, said insertion portion having a maximum transverse dimension not significantly greater than said predetermined diameter, whereby said insertion portion may be inserted into said bore hole with little or no axial force;

(b) said insertion portion comprising a non-perforated wall extending for substantially the full length thereof and adapted for radially outward elastic and plastic deformation; and

(c) mandrel means movable through said insertion portion of said body member to effect said deformation of said wall thereof radially outwardly about substantially its entire perimeter throughout the axial extent of said wall through which said mandrel means is moved, whereby said strata is stabilized solely by frictional, non-piercing engagement by the exterior surface of said wall with the interior of said bore hole.

2. The invention according to claim 1 wherein said body member includes an end portion, integral with said insertion portion and having a maximum transverse dimension larger than said predetermined diameter, said end portion remaining outside

said bore hold after insertion and deformation of said insertion portion.

3. The invention according to claim 2 wherein said end portion is substantially annular in cross section.

4. The invention according to claim 3 and further including an annular ring surrounding at least a portion of said end portion and fixedly attached thereto.

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5. The invention according to claim 4 and further including a bearing plate supported with respect to said body member by said ring to contact the surface of said rock formation surrounding said bore hole.

6. The invention according to claim 5 and further including a washer element encircling said end portion and engaged between said ring and said bearing plate, said washer element having a substantially spherical surface contacting said bearing plate.

7. The invention according to claim 2 and further including a bearing plate and means carried by said end portion for supporting said bearing plate in contact with the surface of said rock formation surrounding said bore hole.

8. The invention according to claim 7 wherein said means carried by said end portion comprises an element having a spherical surface contacting said bearing plate.

9. The invention according to claim 8 wherein said element comprises a washer encircling said end portion of said body member.

10. The invention according to claim 1 wherein at least one of said mandrel means and the interior surface of said insertion portion is coated with a lubricant facilitating movement of said mandrel means through said insertion portion.

11. The invention according to claims 1, 7 or 10 wherein said wall is of uniform cross section over substantially its entire length.

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12. The invention according to claims 1, 7 or 10 wherein said wall is of substantially annular cross section over its entire length.

13. The invention according to claims 1, 7 or 10 wherein said wall includes at least one inward fold extending along substantially its entire length.

14. The invention according to claims 1, 7 or 10 wherein said wall includes a plurality of inward folds extending axially along the entire length thereof.

15. The invention according to claims 1, 7 or 10 wherein said wall is of closed cross section and includes a plurality of inward folds extending axially along the entire length thereof.

16. The invention according to claims 1, 7 or 10 wherein said wall is of open cross section, including a pair of opposing, unjoined edges and a plurality of inward folds extending axially along the entire length thereof.

17. The invention according to claims 1, 7 or 10 wherein said mandrel means comprises a plug of circular cross section tapering from a first diameter at one end to a second diameter at the other.

18. The invention according to claims 1, 7 or 10 wherein said mandrel means is essentially spherical.

19. The invention according to claims 1, 7 or 10 wherein said mandrel means comprises an element separate from said body portion for movement thereinto after said insertion portion is positioned in said bore hole, and withdrawal therefrom after effecting said deformation.

20. A method of stabilizing and supporting a rock formation comprising the steps of:

(a) boring a hole into a surface of the rock formation to a predetermined nominal diameter;

(b) fabricating a hollow, elongated, tubular stabilizer having an insertion portion extending for at least a substantial portion of its length, said insertion portion having a maximum external transverse dimension not greater than said nominal diameter and comprising a wall extending for substantially the full length thereof and adapted for radially outward elastic and plastic deformation;

(c) placing said insertion portion in said hole; and

(d) moving a mandrel through said insertion portion to effect said deformation of said wall radially outwardly throughout the axial extent of said wall through which said mandrel is moved, thereby placing said wall in frictional, non-piercing engagement with the interior of said wall to provide an anchoring force on said rock formation.

21. The invention according to claim 20 and including the further step of removing said mandrel from said insertion portion after deformation of said wall thereby.

22. The invention according to claim 21 wherein said mandrel is rotated as it is moved through said insertion portion to effect said deformation.

23. The invention according to claim 20 and including the further step of applying to at least one of said mandrel and the interior surface of said insertion portion a coating of lubricant facilitating movement of said mandrel through said insertion portion.

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24. The invention according to claim 20 and including the further step of dipping said stabilizer in a lubricant to form a coating on both the interior and exterior surfaces thereof which facilitates movement of said mandrel through said insertion portion.

25. The invention according to claim 20 and including the further step of forming at least one inward fold in said wall along substantially the entire length thereof.

26. The invention according to claims 20 or 25 wherein said stabilizer is fabricated in closed cross section.

27. The invention according to claims 20 or 25 wherein said stabilizer is fabricated from hollow steel tubing.

28. The invention according to claim 20 and including the further step of forming a plurality of inward folds in said wall extending axially along substantially the entire length thereof.

29. The invention according to claim 28 wherein said folds are formed at substantially evenly spaced intervals about the periphery of said wall.

30. The invention according to claims 20 or 28 wherein an end portion of said stabilizer is left outside said hole after insertion therein of said insertion portion.

31. The invention according to claim 20 wherein an end portion of said stabilizer is left outside said hole after insertion therein of said insertion portion, and a load-supporting bearing plate is carried by said end portion and maintained thereby in supporting engagement with the surface of said rock formation surrounding said hole.

32. The invention according to claim 31 and including placing a member in encircling relationship with said end portion to be carried thereby and to contact said bearing plate, said member having a spherical surface contacting said bearing plate.

33. The invention according to claims 20 or 28 wherein an end portion of said stabilizer is left outside said hole after insertion therein of said insertion portion, and said mandrel is moved from said end portion through said insertion portion.

34. The invention according to claims 20 or 28 wherein an end portion of said stabilizer is left outside said hole after insertion therein of said insertion portion, and said mandrel is moved from said end portion through said insertion portion by a driving implement which is subsequently withdrawn from said stabilizer, said mandrel remaining permanently therein.

35. The invention according to claim 20 wherein said wall is solid and unbroken.

36. The invention according to claim 20 wherein said frictional engagement provides the sole engagement between said stabilizer and said rock formation.



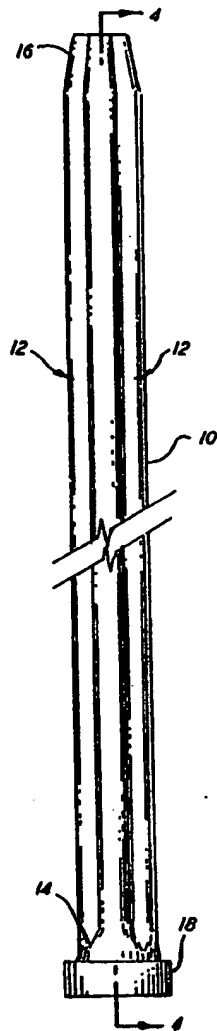


FIG. 1

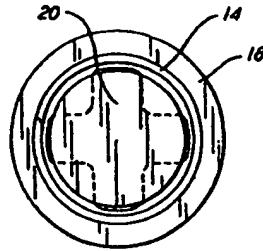


FIG. 2

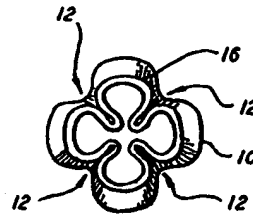


FIG. 3

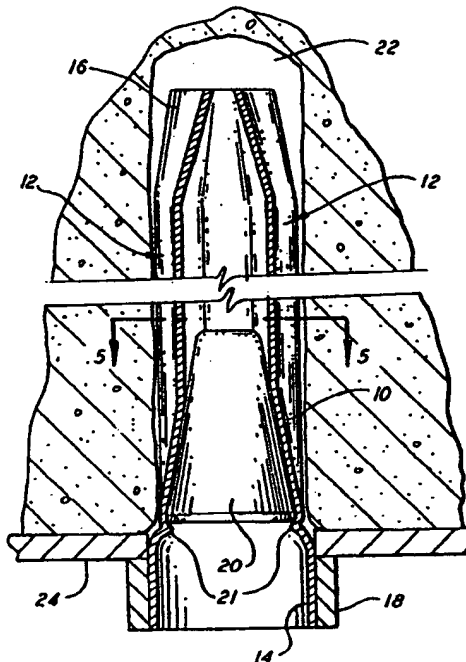


FIG. 4

Alfred E. Mark

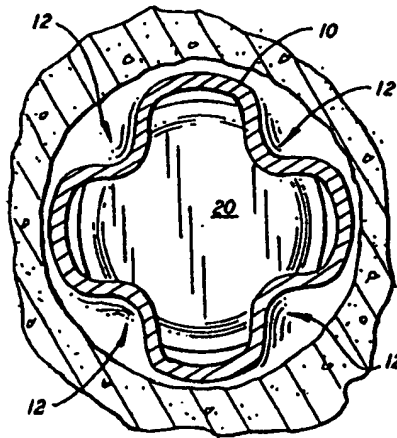


FIG. 5

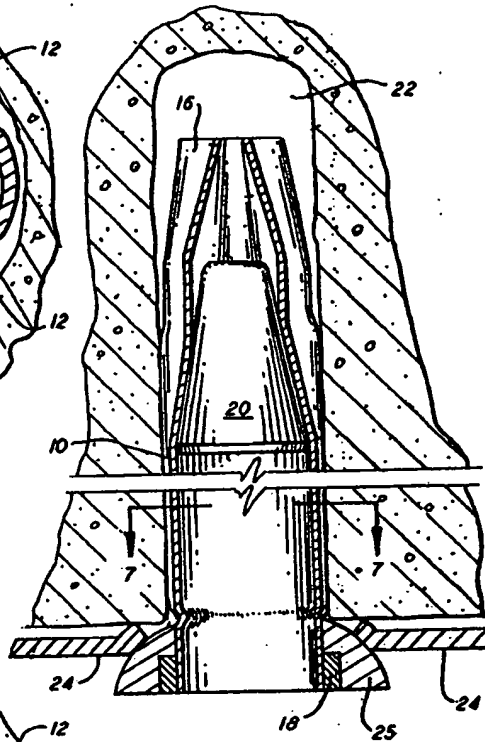


FIG. 6

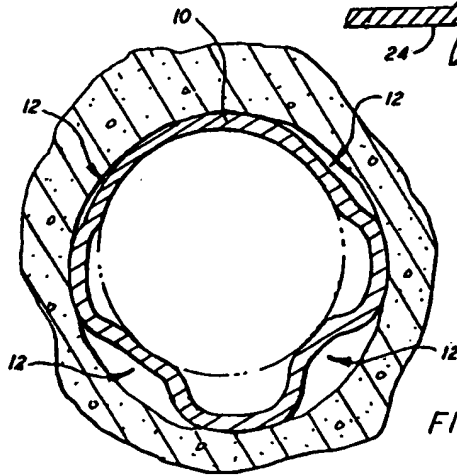


FIG. 7

Alvin E. Mark

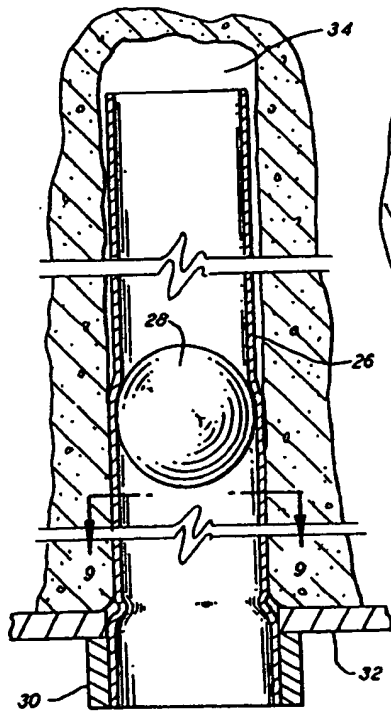


FIG. 8

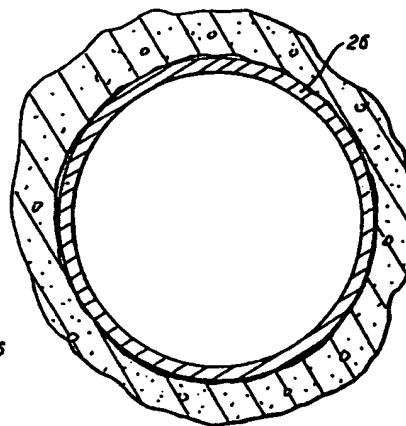


FIG. 9

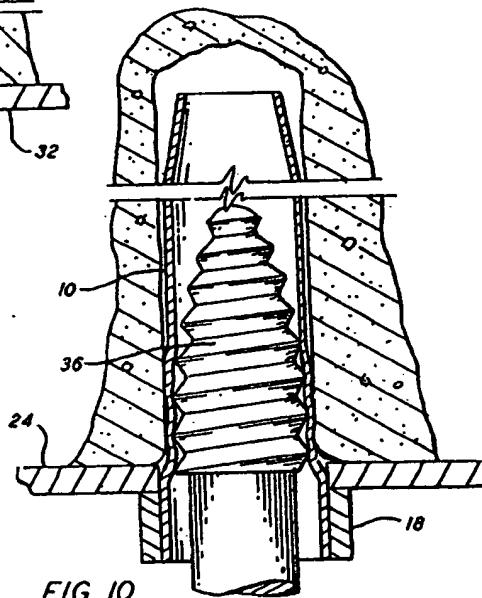


FIG. 10

*also E. M. A. H.*

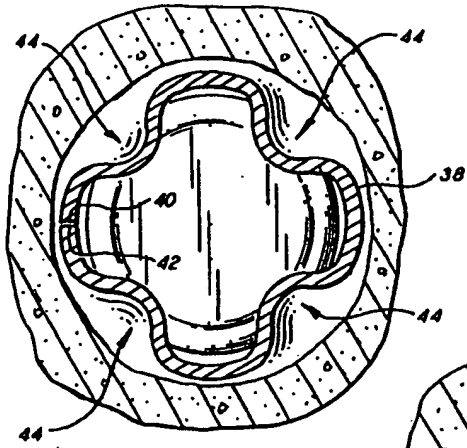


FIG. 11

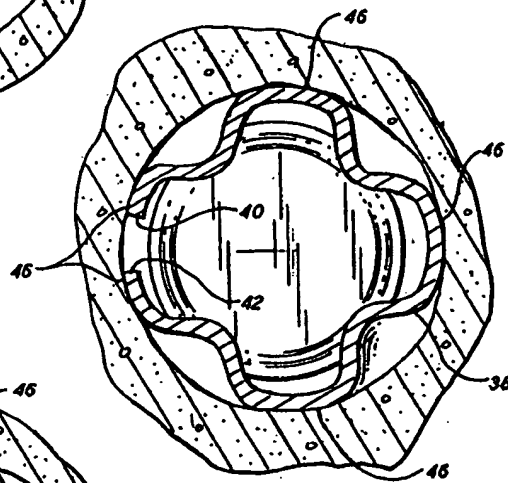


FIG. 12

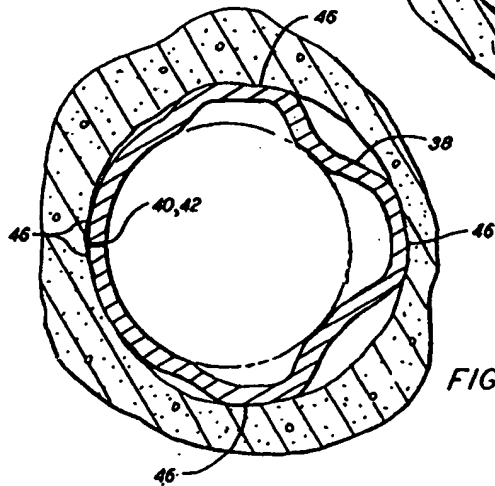


FIG. 13

David M. Markel

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